

Program for Continued Developement and Use of Ocean Acoustic/GPS Geodetic Techniques

Final Report

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Under prior NASA grants our group, with collaboration from scientists at the CalTech Jet Propulsion Lab (JPL), visualized and carried out the initial development of a combined GPS and underwater acoustic (GPS/A) method for determining the location of points on the deep sea floor with accuracy relevant to studies of crustal deformation. Under an immediately preceding grant we built, installed and surveyed a set of the necessary seafloor marker precision transponders just seaward of the Cascadia Subduction Zone off British Columbia. In that 1991 operation we were additionally supported by the Canadian Pacific Geoscience Centre (PGC) for operation of the necessary on-shore reference stations and by the Canadian Institute of Ocean Sciences which provided the needed ship (R/V Tully) to carry out the initial installation. PGC has continued to provide reference station data for our 93, '94, '95, and '96 seagoing operations.

The grant that is the subject of this report provided ongoing support for our group over the period from 1992 through November 1997 to make repeat surveys at this site and at two closely spaced locations spanning the Juan de Fuca Ridge at about 44 deg. 40 min. North Latitude (Cleft Segment) and to analyze the resulting data. During that period there was additional substantial support from the National Science Foundation, particularly in the form of ship time and construction of additional transponders.

The first major operation under this grant took place in the summer of 1993 when we had our first opportunity to return to the Cascadia Subduction Zone site. The ship in this instance was R/V Melville, operated by Scripps Institution of Oceanography (SIO). The necessary sea surface link between the GPS and underwater acoustic parts of the system was provided by use of a buoy tethered to the ship with an umbilical cable about 100 m long. This cable provided both a mechanical, towing connection and a transmission link for both the GPS and acoustic signals. This was the same approach as that used in the 1991 operation. Upon arrival in the area we found that 2 of the 4 prototype transponders installed in 1991 were not replying with adequate reliability. We thus installed 2 additional units and surveyed them in, collecting the necessary GPS/A data. In this, JPL again, as in 1991, provided the necessary GPS antennas and receivers as well as the umbilical cable to bring the signals from the antennas to the ship. Following the expedition the JPL group carried out processing of the GPS data.

1994 saw several major advances. First, we shifted to use of R/V New Horizon, also operated by SIO, in a mode in which the necessary GPS antennas and acoustic interrogation/receive acoustic transducer were all mounted on the ship and surveyed to provide mm level relative position locations for these four elements. Having them on board the ship greatly improved the operational capability for maintaining the data collection elements near the proper location. The second advance was the completion of construction and calibration of a new generation of precision transponders taking advantage of our experience in the 1991 and 1993 field operations. Six of these units were installed as a pair of triangles, closely adjacent to one another on each side of the Juan de Fuca Ridge just south of the midpoint of the Cleft Segment of that ridge. The third advance was the arrival of Dr. C. D. Chadwell as a post doctoral associate. Dr. Chadwell brought with him expertise in surveying and GPS data processing which greatly improved our effectiveness in survey planning and operations. In addition, following the expedition, Chadwell worked with the JPL group (particularly Purcell) to start to relieve them of the routine GPS data processing function by importing the kinematic version of the GIPSY processing system to run on our computers.

The 1994 expedition not only saw the installation and collection of initial data at the Juan de Fuca Ridge, it included a data collection period at the Cascadia Subduction Zone site. The GPS equipment was provided by UNAVCO, while PGC continued to provide the reference station data.

1995 activity included a further data collection expedition to both the Juan de Fuca and Cascadia sites. Improvements in the correlator system used on board ship for the acquisition of the acoustic travel time data increased the reliability of acoustic data by about a factor of 10. An innovative data compression approach devised by JPL was used for the first time by the PGC personnel to ease the problem of recording GPS data at the necessary one second interval. The expedition was successful, with 32 hours of data collection at the Cascadia site netting about 18,000 valid acoustic data points. Similar data series were collected at the Juan de Fuca locations.

1996 field activity was much the same as that in 1995. Following a successful data collection operation at both sites, data reduction efforts were mounted by both Chadwell and JPL, the former carrying out the primary aspects of the GPS and acoustic data processing and the latter developing and applying the necessary software to support the data compression scheme. Cascadia results giving a plate motion vector were produced based on the 94, 95, 96 data sequence. This resulted in a paper accepted for publication in *Physics of the Earth and Planetary Interiors* - the first scientifically relevant contribution by any group in deep ocean geodesy.

Throughout the course of the four year program progress was reported at meetings of the American Geophysical Union, NASA Principal Investigator meetings and other appropriate forums. A listing of the citations for these is appended. Throughout this period we have benefited greatly in the administrative realm from the Federal Demonstration Project under which we were allowed to establish this grant and the companion NSF grants as being related and thus they were considered as joint funding for the program - which they indeed were, with NSF goals primarily related to near bottom surveys of the transponder arrays reported elsewhere.

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